Everyday Products Weren't Always that Way:
Prices of Nails and Screws since about 1700

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1. Introduction

This paper develops price indexes for two very simple, everyday products—nails and screws—and documents dramatic price declines since the mid-1700s, prior to the industrial revolution. Why nails and screws? Nordhaus (1997 and 2007) developed long-span price indexes for lighting and computing, two products that have undergone revolutionary changes.[1] His work showed that these products experienced extraordinary declines in relative prices on a constant-quality basis. This paper looks in a different direction, at two very simple products—nails and screws—that have changed relatively little over the centuries and today seem quite everyday and commonplace. However, just as a range of innovations pushed down the price of lighting and computing, technological innovations in an earlier period pushed down the prices of nails and screws. Indeed, the manufacturing processes for nails and screws (as well as those for upstream iron and steel products) were the focus of intense innovation and productivity improvement in an earlier period.[2] While Nordhaus highlighted the extraordinary price declines of products undergoing revolutionary changes, this paper shows that simple, everyday products also experienced consequential price declines. The rapid declines in relative prices of nails and screws have left these products seeming everyday and commonplace today; however, in an earlier era, the relative prices of nails and screws was much higher, and the place of these products in the economy was vastly different than it is today.

Using the preferred price index developed in this paper, the real price of nails on a quality adjusted basis fell—relative to a broad bundle of consumption goods as measured by the overall CPI—by a factor of about 15 from its peak in the mid-1700s to the middle of the 20th century,

[1] Nordhaus refers to changes in revolutionary products as "tectonic shifts," as compared with changes in other products that experienced "run-of-the-mill" changes or that were "seismically active."
[2] The iron and steel industry, of which nails and screws make up just one narrow slice, has been studied extensively. For example, see Temin (1964).

averaging a decline of 1.3 percent a year. (Prices have risen some in the past several decades.) As described below, the large price drop reflected radical changes in the production process for nails, mirroring many key milestones of the industrial revolution. For example, prior to the industrial revolution nails were produced one at a time by a blacksmith, and according to Rybczynski (2000, p. 70-71), it took about a minute to produce a single hand-forged nail. Currently, a nail-making machine with a footprint of about three square feet can produce 300 to 450 wire nails in a minute.

Regarding screws, price and quantity data are sparser than for nails and so conclusions about price changes must be more tentative. That said, the estimates in this paper suggest that the real price of screws also dropped dramatically—by a factor of about 8 times from the mid-1700s to the late 1800s—reflecting many of the same factors that lowered prices for nails. Over the 150 years of steep price decreases, this decline also averaged 1.3 percent a year.

While the real price declines for nails and screws are not on the scale of lighting or computing, they are consequential nonetheless, and the much higher relative prices in the late 1700s had important consequences for patterns of economic activity. In that earlier period, nails were both more precious and a more important component of economic activity.

In terms of being more precious, the dome of the Maryland State Capitol, completed in 1788 and made largely of wood, was joined together with no nails but rather with wooden pegs and iron straps. Presumably, this choice was made, at least in part, because of the high cost and limited availability of nails at the time.[3] And, nearly a century later, nails were still highly valued (and preferred to wood pegs), as can be seen from the following quote from *Little House*

[3] See Maryland State Archives (2011). The high value of nails during the 1700s is highlighted by the practice of burning down abandoned buildings to facilitate recovery of the nails (see Temin (1964, p. 42)).

on the Prairie (Wilder, 1935, p. 124). The quote describes attaching a roof to a log home on the frontier during about the 1870s (after the price of nails had already fallen significantly from the late 1700s):

> Now Pa carefully took the nails one by one from his mouth, and with ringing blows of the hammer he drove them into the slab. It was much quicker than drilling holes and whittling pegs and driving them into the holes. But every now and then a nail sprang away from the tough oak when the hammer hit it, and if Pa was not holding it firmly, it went sailing through the air.
>
> Then Mary and Laura watched it fall and they searched in the grass till the found it. Sometimes it was bent. Then Pa carefully pounded it straight again. It would never do to lose or waste a nail.

Regarding the importance of nails in overall economic activity, this paper also reports domestic absorption of nails, going back to 1810. At that time—more than 20 years after the Maryland State Capitol was completed—nails are estimated to have amounted to about 0.4 percent of nominal GNP. In today's terms, this share is similar to that of household purchases of personal computers and peripherals or of airfares. As prices plunged during the 1800s, domestic absorption rose dramatically. But, as a share of nominal GDP, domestic absorption of nails, which once were quite important, have become de minimus. So, while nails appear everyday today, that perception reflects a couple hundred years of significant declines in their relative price.

Nails and screws also are interesting from the perspective of price measurement. They are relatively simple products whose physical characteristics have not changed so much over the centuries—thereby facilitating the construction of quality adjusted price indexes spanning long time periods. Yet, nails and screws did undergo some important changes in their characteristics; however, these quality changes were straightforward enough that, to a significant extent, their

effects can be directly measured. Nonetheless, constructing a quality adjusted price index for even these relatively simple products is challenging, and the paper highlights, in a transparent way, some of the same measurement issues that have confronted researchers constructing quality-adjusted price indexes for more complex goods and services. Finally, this paper also raises some puzzles and possible inconsistencies across PPIs and official measures of import prices for nails and screws.

This paper is organized as follows. To provide some context, the next section reviews a timeline of key milestones in the development of nails and screws. Section 3 discusses the construction of the price indexes for nails and focuses on the implications and interpretation of the long-span time series for nail prices. Section 4 focuses on prices of screws. Section 5 concludes.

2. A Brief History of Nails and Screws

Nails

Table 1 presents a brief historical time line for nails.[4] Nails fall into three broad types—hand forged, machine cut, and wire—with each of these types dominant in each of three overlapping periods. Hand-forged nails have been made at least since Roman times and continued to be made in relevant quantities through about 1820. Forged nails are made by a blacksmith (or nailsmith), hammering the nail from a rod of iron and hammering a head on the

[4] A number of authors have described the history of nails. For example, see Adams (2002), Lewis (1998), and Wells (1998). The description here summarizes key points from that literature. The particular facts coming from different sources are noted in table 1, and for expositional simplicity, the source notes are not repeated in the text.

top. According to Rybczynski (2000, p. 70-71), an experienced nailsmith could produce a nail from a blank in about one minute.

Cut nails are made by a bladed machine that cuts nails from thin strips of iron or steel. The first patents for cut nails in the United States were granted in the 1770s and 1780s, and a flood of patents followed in subsequent years. The manufacturing technology for cut nails improved dramatically during the 1800s, mirroring many of the developments of the broader industrial revolution. The power source shifted from water to steam and later electricity, and the machinery became increasingly automated requiring less and less operator intervention.[5] In the 1880s, production shifted from iron to steel nails.

By the 1880s wire nails became more prevalent, with the first U.S. patent for wire nails granted in 1877. Initially, wire nails were made from iron wire. By the late 1880s and early 1890s, wire nails were being produced from steel wire in sizable quantities. Wire nails are made by cutting each nail from a coil of drawn wire, sharpening a tip, and adding a head. Wire nails remain the dominant type used for most purposes today, though cut nails are still used for some specialty applications. For wire nails, the manufacturing technology also has improved considerably in the decades after the 1880s.

Figure 1 illustrates each of these three types of nails. The top nail is a hand-forged nail; the middle one is a cut nail, and the bottom one is a wire nail. The hand-forged and cut nails look rather similar and, indeed, they have similar holding power (or resistance to being withdrawn after being pounded in). One advantage of hand-forged nails over early machine cut nails is that forged nails could be "clinched": that is, the tip of the nail that extended through the

[5] Wells (p. 85) notes that the iron sheets used to make nails were rolled by water-powered equipment in 1810 in a Philadelphia factory and that steam power was used in a Pittsburgh rolling mill a year later.

pieces of material being joined could be bent over, or clinched, thereby increasing the holding power of the nail. Early machine cut nails had the grain of the metal running perpendicular to the length of the nail, and cut nails would break if an effort were made to clinch them. Later, cut nails were made with the grain of the metal running parallel to the length of the nail, and these cut nails could be clinched. Wire nails have considerably less holding power than forged or cut nails, but, because each nail is lighter, shipping costs per nail were less. The basic wire nail has changed relatively little since the 1890s, with the graphic in early Sears catalogues depicting a nail that looks much like one that could be purchased at Home Depot today.

From the mid 1700s—when it took, perhaps, a minute to make a single nail—to today, the changes in nail manufacturing technology are rather stunning. As noted, today, a nail-making machine with a footprint of about three feet square and produce 300 to 450 nails per minute. If we assume that one worker can operate 4 machines at once and that each machine produces 350 nails a minute, then labor productivity of nail production has increased by a factor of 1400 times since the era of hand-forged nails when it took a worker about a minute to produce a nail. With most of this change occurring over the period from 1790 to 1940, the annual rate of increase in labor productivity was nearly 5 percent a year; much slower than the pace of productivity advance in the production of computers in recent decades, but still significant.[6] Beyond improvements in the manufacturing technology, the varieties of nails produced has expanded significantly over the years, including nails with coatings to prevent rust and with rings around the nail's shank to increase holding power. Indeed, the online catalog of a current American nail manufacturer lists 107 distinct varieties of nails, not counting different sizes of the

[6] Based on $1400^{(1/150)}$

same type of nail.[7] In addition, the advent of nail guns has dramatically changed the way that nails are installed, and the implications of nail guns for price measurement are discussed in section 3.

Screws

Table 2 shows a timeline for screw manufacturing.[8] According to a number of observers, screws first began to appear regularly in the historical record in the 1500s. At this point, screws were not a commercial article, and they were often made as needed by builders of clocks, locks, watches, and guns. In this early period, screw threads were filed by hand on forged blanks, and they were blunt ended without pointed tips (meaning that they were not self-starting and bore holes needed to be drilled). In addition, the hand filing meant that every screw was different and so not interchangeable. The slot on the head of the screw was filed in a separate step. It appears that it took several minutes to make a screw, though I have not found very precise evidence on this point.

Screws became a commercial article in the mid 1700s, and the fist patent for making wood screws by machine was granted in the United Kingdom in 1760, though production did not start for another 15 or so years.[9] These machines chucked the screw blank in a set of jaws so that it could be rotated against a blade that cut the thread. According to an account written in 1866 (Chamberlain), the quality of these early screws was extremely low, and, except for specialized applications, screws could not compete with nails. The first screw factories were

[7] Catalog available at www.mazenails.com. The list of nail varieties is on page 4 of the 2010 catalog.
[8] The summary in the text is based on the material cited in Table 2. For expositional clarity, the source notes are not repeated in the text.
[9] It is believed that one spur to screw production was the development of butt hinges, for which a patent was issued in 1775; for example, most modern doors are hinged with butt hinges that attach to the surface of the door that adjoins the frame. These hinges needed to be attached with screws because nails did not have enough holding power and would pull out as the door was opened and closed repeatedly.

established in the United States around 1810, and a boom in screw making (centered in Rhode Island) was underway by the 1830s, though the basic production technology had not changed much since the late 1700s. During the 1830s and 1840s, many U.S. patents were granted for improved screw-making machines, and production of screws with pointed tips had become fully automated by 1849. In 1864, a standard for screw threads was adopted in the United States, facilitating interchangeability. Although the machinery continued to improve, the basic slotted wood screw did not change much from the late 19th century through to the present. Indeed, the graphic for flat, slotted head wood screws that appeared in the 1896 Sears catalogue depicted much the same screw as that in the 1971 catalog, the last year in which Sears listed a wide range of sizes of wood screws in its catalog.

An important innovation for screws was the development of alternatives to slotted heads. A screwdriver can easily slip out of a slotted head screw and so it is difficult to use power drivers for slotted head screws. In addition, it can take a bit of fussing to get a screwdriver lined up with the slot. The first significant alternative was the Robertson screw, patented in 1907, with its square socket drive. The patent on Phillips head screws was granted in 1936. These alternatives to slotted-head screws facilitated the use of power drives, with Phillips screws first tested on automobiles in 1936, and, within a few years, most U.S. auto manufacturers had switched to Phillips screws.[10]

[10] The Robertson square-socket and Phillips-head screws provide an interesting QWERTY-type example of diffusion, as described in Rybcyzinski (2000, p. 79-86). The Robertson screw was developed first, and according to a 1995 Consumer Reports article, the Robertson screw dominates the Phillips screw in a number of important functional characteristics. However, Phillips had more success as a salesman and, in the United States, Phillips screws came to dominate Robertson screws. (Robertson was Canadian, while Phillips was American.)

Just as for nails, improvements in the manufacturing technology have been significant. A modern screw-making machine can produce as many as 35 1" screws in a minute.[11] Again, let's assume that a worker can operate four machines simultaneously, implying an output of 140 screws per minute. For the earliest hand-filed screws, let's assume that the reference to several minutes per screw amounts to five minutes. Under these assumptions, labor productivity increased by a factor of 700. If this increase occurred over the period between 1775 and 1940, then the annual rate of increase was 3.9 percent.[12]

3. Price Indexes for Nails

Raw Nominal Data and Conversion to Real Prices

Figure 2a plots the raw data on the nominal price of nails in cents per pound; all the price quotes I found for nails were on a price per pound basis. In the figure, different colors capture the different "regimes" of data. (The data are also reported in the Appendix.) Table 3 provides details on the sources from which these prices were drawn. The green segment refers to prices from Beveridge (1939) for nails in the United Kingdom from 1695 to 1792.[13] Given the time period, these quotes must have been for hand-forged nails. The quotes cover a wide range of sizes, with prices provided in U.K. shillings per 12 pounds of nails. I converted these prices to cents using an exchange rate from U.K. pounds to U.S. dollars for 1792.[14] Thus, before 1792,

[11] Based on spec sheets found on machinetools.com for an Abhijat single-spindle automatic screw machine, model number AL-25.
[12] Based on $700^{(1/165)}$.
[13] The original source of Beveridge's price quotes for nails is fascinating. In particular, he obtained logs of purchases made by the Greenwich hospital. This hospital entered pretty much everything it bought into a log book, and it provides a rich data source.
[14] The exchange rate used for 1792 is $4.47 per U.K. pound sterling. The exchange rate is from the Measuring Worth website at www.measuringworth.com.

these prices are capturing movements in prices in the United Kingdom, indexed to the 1792 value in cents per pound.

The blue segment in figure 2a captures prices from Cole (1938) for the period from 1784 to 1813. The type of nail is not specified; given the time period, these quotes probably cover a mix of hand-forged and cut nails, and I refer to this stretch of data as “mixed.” The quotes in Cole are for various size lots, and they were all converted to cents per pound of nails.

The red segment covers machine-cut nails from 1814 to 1890. From 1814 to 1828 the prices are from Cole (1939), while the quotes extending through 1890 are from various sources and, like Cole’s data, were reproduced in *Historical Statistics of the United States.* The quotes are for dollars per hundred pounds and were converted to cents per pound.

The black segment in figure 2a covers the period from 1890 to the present and refers to wire nails. This segment incorporates data from the Bureau of Labor Statistics, reflecting a number of different reports for the earlier periods and producer price indexes (PPIs) in the more recent periods. The quotes are for different varieties of nails and are quoted for lots of various sizes. All of these quotes were converted to cents per pound.[15] The orange dot reports a price quote for 2011 from Amazon.com for $50 pounds of nails converted to cents per pound.

In a perfect world, an index of nail prices would be constructed by using shipment or consumption weights to aggregate prices of each type of nail. Data limitations make that impossible, and the choice of breakpoints in price quotes across the different types of nails is largely driven by data availability. That said, the switchovers to cut nails in1814 and to wire

[15] Starting in 1992, the PPI provides index numbers—rather than prices in natural terms—and these PPIs are used to extend the price series on a cents per pound basis.

nails in 1890 are consistent with what archaeologists characterize as the eras in which each type of nail was prominent.[16]

At these switchover points, as can be seen in figure 2a, there are some discontinuities. In the late 1700s, the series for forged nails the United Kingdom (shown in green) is below the series for "mixed" nails (shown in blue) in the United States. This gap could reflect any of a number of factors. Perhaps nails were produced more cheaply in the United Kingdom in this period. But, shipping nails was expensive so if shipping charges were added to the U.K. prices, they might look more like the higher U.S. prices during this period. In addition, the descriptions of the nails for which quotes were collected are pretty sketchy so there likely are differences in what is being priced. The other interesting overlap is that between the series for cut nails and wire nails. It appears that wire nails were more expensive, raising the question of why buyers shifted to wire nails, particularly given their less impressive holding power. This issue is discussed further in the next section on quality adjustment.

I also collected a parallel time series of prices from Sears catalogs.[17] These quotes extend from 1897 to 1960, the last year the Sears catalog included steel wire nails in a variety of sizes. As noted, this analysis focuses primarily on the BLS prices for nails, though below I compare the BLS prices to the Sears prices and discuss the differences.

To calculate real prices, I constructed a CPI back to 1695 by linking together series for the U.K retail price index (RPI) from 1695-1784 and various measures of the U.S. CPI from

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[16] See figure 8 in Wells (1998).

[17] Economists have a long tradition of using Sears catalogs (and those from other retailers), including work by Albert Rees (1961) and Robert Gordon (2008).

1784-2011.[18] This CPI series is shown in figure 2b. The base year for the CPI series is 2010 so the real price measures shown are in terms of 2010 dollars. Of course, as Gordon (2008) and many others have noted, comparisons of CPIs over very long spans of time raise a host of difficult issues. Nonetheless, it seems more relevant to focus on real prices—despite the inherent limitations—rather than nominal prices, particularly given the central interest in the prices of nails and screws relative to prices of other goods and services.

Real prices of nails, relative to the CPI, are shown in figure 3a on a cents per pound basis from 1695-2011. The real price on this basis was relatively stable from 1695 through the early 1800s (at least compared with the large decline that followed), and the real price exhibited a peak in the mid 1700s. Over most of this period, the prices refer to hand forged nails. Then, during the 1800s, the price fell dramatically, dropping from about 160 cents per pound around 1800 to a little less than 30 cents per pound by 1930. Since then, prices on this basis jumped in the late 1940s and 1950s and then fluctuated in a fairly wide range through 2011.

Quality Adjustment

One important difficulty with the prices on a cents per pound basis is that cents per pound does not price a homogenous product but rather is conflating prices of nails of many different sizes. When nails are purchased, buyers likely are thinking of a particular project for which they need a certain number of nails of a certain size. So, to standardize the size of nails in the index, I

[18] For 1784-1800, U.S. CPI data are from Officer (2011); for 1800-2010, CPI data are from the Minneapolis Federal Reserve's website; and for 2011 the figure used is the 12-month change in the CPI for April 2011.

convert everything to be as equivalent as possible to a 2”, size 6d nail.[19] For the earlier periods before nails sizes were standardized, I standardize on 2” nails.

Table 4 shows the counts of nails per pound used for this conversion and the sources from which these counts were drawn. Forged and cut nails are pretty similar in general shape (as can be seen in figure 1), and I use a count of 85 per pound for both forged and wire nails. Wire nails are considerably thinner, and as the quotes switch to wire nails in 1890, the count jumps to 150 for size 6d 2” nails. This jump in the count of nails per pound helps to explain why, on a cents *per pound* basis, the price of wire nails was initially higher than the price of cut nails. The count briefly jumps to 181 during the second World War when nails available to the public became thinner, presumably to conserve essential war materials. After the war, the count dropped back to 168, where it has remained since.

Using these count estimates, figure 3b puts real prices on a cents per nail basis. One key difference is evident between the upper and lower panels. On a *per nail* basis prices fell by a larger multiple than on a per *pound* basis. In particular, note what happened around the period of transition in price quotes in 1890 from cut nails to wire nails. On a *per pound* basis, wire nails look more expensive than cut nails but on a *per nail* basis wire nails look less expensive than cut nails. The reason for this difference is the higher count of wire nails per pound than of forged or cut nails. Although, as discussed below, wire nails have less holding power than cut nails, Temin (1964) pointed out that their lighter weight per nail meant lower shipping costs per nail, and this factor also enhanced the attractiveness of wire nails. This discussion highlights the importance, for the purposes of price measurement, of being as precise as possible about the product being priced.

[19] The “d” in 6d refers to the size of the nail. A 6d nail often is referred to as a 6-penny nail.

As noted, wire nails have less holding power than cut or forged nails. This outcome occurs primarily because the cross section of a cut or forged nails is rectangular and tapered compared with the round and untapered cross section of a wire nail. The greater holding power comes from the wedging action arising from the shape of the cut nails. In the world of wood engineering, these differences in holding power have been measured, and the literature suggests that cut nails have about twice the holding power of wire nail.[20] Figure 4a repeats the plot of real prices on a cents per nail basis from figure 3b and adds a sequence of dashed lines showing real prices in terms of cents per nails *with prices for the period before 1890 adjusted for the greater holding power of cut and forged nails by dividing prices in the earlier period by two.*

One could interpret this adjustment as a simple hedonic correction for a one-time change in quality. And, to the extent that holding power is the only relevant characteristic, this adjustment puts prices in the earlier period on constant-quality basis, relative to the period with wire nails since 1890. Of course, holding power is not the only relevant characteristic. For many applications, the smaller holding power of wire nails is perfectly sufficient so that the greater holding power of cut nails would be unnecessary. (Note the analogy to the discussion of how much users value increases in the speed of personal computers beyond a certain point.) Moreover, in many applications using wire nails it is possible to use additional nails to gain holding power.[21]

[20] Stern (1952) finds that 2½" plain shank brads (wire nails) have 140 pounds of holding power immediately after being pounded into wood and about the same amount after a year. He finds that 2½" cut flooring nails have about 360 pounds of holding power immediately after being pounded in and about 235 pounds after a year. The ratio for immediate holding of cut to wire nails is 2.6, and the ratio after one year is 1.7. Similarly, the *Woodworking Newsletter* (2009) from Lee Valley reports that "Academic studies of [cut and wire nails] show that cut nails have somewhere between 65 percent and 135 percent more holding power than wire nails." (Lee Valley is a popular seller of woodworking tools and hardware.) I take this information as being consistent with cut nails having about twice the holding power of wire nails.

[21] In a perfect world, I could run a hedonic regression on a panel of prices in the period when cut and wire nails were both prevalence to see how the market priced holding power. Data limitations make that a tough thing to do.

As noted, shipping costs are another characteristic that would be important to some buyers. For example, the 1897 Sears catalog indicates that shipping costs for a 100 pound keg of nails from Chicago to Boston amounted to about 20 percent of the price of the nails. Given the greater number of wire nails that would be in a keg compared with the number of cut nails, shipping costs per nail would have been considerably lower for wire nails than for cut nails. Some simple calculations suggest that these differences would close a chunk of the discontinuity in 1890 between the prices shown in figure 4a for cut and wire nails on a constant holding power basis.[22] In particular, if shipping costs were to be added in, the dashed lines in figure 4a would shift up by more than would the black solid line. I do not explicitly adjust for shipping costs, though the matched model index described below does implicitly control for these differences in shipping costs.

Finally, to construct a single index for the full time span that controls for these factors and holds quality constant as well as possible with the available data, I construct a matched-model index, linking prices across the switchover points. While the matched-model approach surely misses some important differences, it seems the best way available to construct a single price index that, as much as possible, holds quality constant across the characteristics. Specifically, I use the prices shown in figure 4a: the U.K prices (converted to U.S. currency) from 1695-1784, the series labeled “mixed” from 1784-1814, the series labeled “cut” from 1814-1890, and the series labeled “wire” from 1890-2011. (For the matched model index, I would generate the same index whether I use the series for forged and cut nails that have been adjusted

[22] For example, in 1897, a 100-pound keg of 2”, 6d wire nails was listed in the Sears catalog for $1.85; a keg of cut nails was listed for $1.80. Fourth-class freight from Chicago to Boston was 39 cents. With 85 nails per pound in the keg of cut nails and 150 nails per pound in the keg of wire nails, shipping costs would have amounted to 0.0026 cents per nail for wire nails and 0.0046 cents per nail for cut nails. And, with a CPI in 1897 of 3.81 (2010=100) the real cost per nail for shipping was 0.068 cents per nail for wire and 0.12 cents per nail for cut.

for holding power or those that have not been adjusted.) In each of the crossover years (1784, 1814, and 1890), I use the price from the more recent type of nail and link backwards from that year using price changes for the earlier type of nails in the earlier years. This series is plotted in figure 4b and shows that real prices of nails fell by a factor of about 15 times from its peak in the mid 1700s to its low point in the middle of the 20th century.

An additional important innovation is nail guns, with pneumatic guns appearing in the Sears catalog in the early 1980s. Nail guns raise the question of what is the nail-related product being priced? If it's an individual nail, then nail guns can be regarded as a distinct piece of capital equipment; however, if the product to be priced is an *installed* nail, then nail guns should be considered an integral part of the process of installing nails along. An all-in price for installed nails would include materials (the nails), capital costs (hammer v. nail gun), labor costs, shipping, and everything else. Although I have not calculated an all-in price across all years, the following illustrative example highlights that nail guns are a big deal.

Today on Amazon.com, a high-quality nail gun that shoots 2" nails can be purchased for $175, and a small compressor and air hose costs $214. Packs of nails for the gun are about $41 per 5000 nails. In contrast, a hammer costs about $9.[23] Assume that a nail gun and compressor lasts 6 years in commercial applications and experiences straight-line depreciation over that period (assume the same for the hammer). Further, assume that the hourly wage for a construction worker is $20 per hour.[24] Finally, assume that a worker with a hammer can install 6 nails per minute and that worker with a nail gun can install 20 nails per minute. With these

[23] Prices were pulled from Amazon for Porter-Cable FR350A framing nailer ($174.55), a Makita MAC700 compressor ($194), and a 50' air hose ($19.99).
[24] The BLS' employment report for June reported average hourly earnings in construction of $25.36. I assume that a construction worker who primarily installs nails is somewhat less skilled than an average construction worker and is paid a bit less.

assumptions, the cost per *installed* nail for a worker using a hammer is 6.2 cents per nail (including the cost of the nail, the cost of capital per nail, and the wage per nail). The cost per installed nail for a worker using a nail gun is 2.5 cents per nail, about 60 percent below the cost using a hammer.[25] If we were to port this difference over to the matched-model price index for nails shown in figure 4b, then the advent of nails guns can be seen to be a pretty big deal. For example, the price of a nail in for 2011 is just over 0.5 cents per nail. If this price were lowered by 60 percent, it would be about 0.2 cents per nail, which would pull the price back down close to its all-time low.

As noted earlier, I also collected prices for nails from Sears catalogs from 1897 to 1960, though quotes are not available in all years, notably during 1898 to 1910.[26] The appeal of these prices is that it is straightforward to hold quality constant. For example, it is possible to track the price of 2”, size 6d nails over this period. The Sears prices for steel wire nails that are 2” long and size 6d (converted to real prices) are plotted in figure 5a on a cents per pound basis and in figure 5b on a cents per nail basis. The quote from Amazon for nails of this size also is plotted in the figure.

As can be seen the Sears prices track the prices from the PPIs pretty closely through about 1940. This suggests that the PPIs, converted to a cents/nail basis, are doing a reasonable job of capturing price changes for the 2” long, size 6d nails that the Sears series is tracking. Starting after 1940, the Sears price rises considerably more rapidly than does the series based on

[25] Additional assumptions are that a full time worker is employed for 2000 hours a year and that the worker spends 500 hours installing nails and 1500 hours arranging materials and undertaking other tasks; accordingly, the labor cost allocated to installing nails is $10,000 (=$20x500). On these assumptions, the worker would install 600,000 nails in a year with a nail gun (=20x60x500) and 180,000 nails with a hammer (=6x60x500).

[26] During this period, the Sears catalog noted that nail prices (which were sold in 100 pound kegs) were volatile and that buyers should request an up to date price list. I have not been able to track down these price lists. For shorter periods in which I could not or did not collect quotes, I interpolated between years in which quotes were collected.

PPI indexes. I am unsure of the source of this difference, but it could reflect a shifting wholesale/retail margin at Sears. The PPI quotes (and the quotes for the earlier periods) are producer prices. The Sears price is, technically, a retail price, though in the late 1800s and the first part of the 1900s, Sears sold nails in large volumes (100 pound kegs) and sold them directly to homebuilders (inferred from the advertising copy in the catalogs). In the later period, it appears that the Sears catalog was catering exclusively to retail purchasers of nails. In particular, starting in the mid 1930s, Sears began quoting prices for 1 pound packages and in the early 1940s began quoting prices for 5 pound packages; by this time Sears no longer quoted prices for 100 pound kegs in their catalog. These changes support the view that Sears shifted from being more of a wholesaler to more of a retailer in the market for nails. Such a shift could be consistent with a rising retail margin accounting for the more rapid increase in Sears prices relative to the PPIs over the same period.

Another possible explanation for the differences between the Sears prices and the PPIs is that the Sears prices are more precisely controlling for quality change by tracking prices of nails of the same size and quality—though, as noted, sold in different lot sizes in different periods—while, perhaps, the PPIs were missing changes in the mix of products included in the index. One data point that argues against this interpretation is the price quote for 2011 from Amazon.com. As noted, this quote is for a 50 pound lot of 2”, size 6d, wire nails without shipping. This price is fairly close to that generated from the PPIs and suggests that the PPI was reasonably on track with wholesale prices for 2”, 6d nails in 2011.

Interpretation and Implications

Looking again at figure 4b, the real price of nails fell by about 1/3 from the mid 1700s to about 1800. Presumably, these price declines reflected many of the types of process improvements that Adam Smith (1776) noted for pins as well as the beginning of the machine-cut nail era. During the 1800s, prices plunged, with the sharp drop continuing through to the 1940s. All told, prices fell by a factor of 15 from their mid-1700s peak to their mid 1900s trough. Then, prices rose in the 1950s and 1960s, dropped back some through the early 2000s and then rose somewhat again.

Focusing on the period of rapid declines in real prices of nails, these rapid declines contributed to a huge increase in demand. Figure 6a shows domestic absorption of nails for selected years (the data points are shown as red dots that are connected by line segments).[27] As can be seen, domestic absorption rose dramatically, from nearly 16,000 tons of nails (including spikes, tacks, and staples) in 1810 to over 200,000 tons in 1872 and more than 1.6 million tons in 2002. This pattern, of falling prices and rising quantities, suggests that the supply curve was shifting outward as production technology improved, leading to falling prices along the demand curve. No doubt, the demand curve also was shifting out to some degree as the U.S. economy expanded. As noted above, changes in production technology for nails was quite dramatic from

[27] I calculate absorption as production plus imports less exports. From 1872 forward, the data are mostly from *Annual Statistical Reports* of the American Iron and Steel Institute (AISI and known as the American Iron and Steel Association in earlier years). For 1810, I could only find data on production (French (1858, p. 18)), and based on his description that imports of nails were significant until the War of 1812, I arbitrarily doubled the production figure to get a figure for domestic absorption. For the 1992 and 2002 observations, I pulled numbers on the value of production from the Census of Manufactures and used numbers on exports and imports from the AISI reports. The AISI numbers and the Census of Manufactures numbers for production may not be comparable. Finally, the numbers for value of production from the American Iron and Steel Institute covering the latter part of the 1800s and the early part of the 1900s are larger than the numbers from Shaw (1947). I have not yet tracked down the source of that difference.

the late 1700s through the latter part of the 1800s. In addition, innovation in upstream industries (iron and steel) also likely played an important role in falling prices for nails.[28]

Although domestic absorption of nails may seem small in 1810, nails actually were an important part of the economy at that time. For 1810, I estimate that domestic absorption of nails amounted to over 0.4 percent of GDP on a current-dollar basis. To put this into perspective, 0.4 percent of GDP in 2010 amounted to $58.6 billion (=.004 x $14660.4). Moreover, by way of comparison, household purchases of personal computers and peripheral equipment amounted to 0.4 percent and household purchases of air travel amounted to 0.34 percent. So, nails were a big deal in the 1700s and early 1800s.[29]

Despite the huge increase in quantities, with the drop in price, domestic absorption of nails as a share of GDP (GNP in earlier years) fell very substantially. The blue dots in figure 6a show domestic absorption of nails as a share of GDP, showing the decline in share from an estimated 0.4 percent in 1810 to just over 0.01 percent in 2002. The drop shown in the figure highlights the transformation of nails from an important product in the U.S. economy to an everyday product that is, largely, taken for granted, and whose consumption is a trivial fraction of GDP. Put another way, with dramatic changes in relative prices, the role of nails in the economy changes significantly, as did our perception of them.

That nails loomed large in the U.S. economy in the late 1700s and early 1800s can also be seen by considering construction, the main downstream industry that benefited from the decline in the price of nails. First construction was relatively more important in the U.S. economy in that earlier period than it is today. For example, according to Gallman (1966) gross

[28] See Temin (1964) for a discussion of developments in the broader iron and steel industry during the 19th century.
[29] And, nails often were included in measures of industrial production and price indexes for the 1800s. For example, Hansen (1916) included nails in his wholesale price index for 1801-1840.

investment in construction (including farm improvements) amounted to about 16 percent of nominal GNP in 1839, compared with 7½ percent in 2008 (and about 5 percent in 2010).[30]

Second, a simple thought experiment highlights the relative importance of nails in construction around 1800. In 1798, a relatively simple house (24' x 36' with 7 windows) in Warren, Connecticut was valued at $50.[31] This house likely was built with few nails, but, as a thought experiment, let's suppose that it were built primarily with nails rather than other joinery. Current estimates suggest that a 1200 to 1500 square foot house would require about 250 pounds of nails for construction. Suppose that the 1798 house would have required 50 pounds of nails because of its smaller size and simpler construction. (Recall too that 50 pounds of nails in 1798 would amount to considerably fewer nails than would 50 pounds today.) Given nail prices in 1789 of $12.00 per hundred pounds, the nails for that 1798 house would have cost $6.00, more than 10 percent of the value of the house!

Even by 1910, let alone by today, nails made up a pretty trivial part of the value of a house. According to the 1910 Sears' Homebuilders catalog, a 9-room house could be constructed for $2782, including the cost of the kit from Sears and the cost of labor (but not the land). If this house required 250 pounds of nails to build, the nails for the house would have cost $4.73 (=250 pounds x $.0189 per pound), less than 0.2 percent of the cost of the home.

The evolution of nails in the United States highlights another common development in manufacturing; namely, the rise of serious foreign competition in the second half of the 20th

[30] Gallman reports gross capital formation for new construction (including both residential and nonresidential) of $137 million in 1839 in current dollars. This figure excludes $133 million of the value of improvements to farmland made with farm construction materials. If the farm figure is added in, gross investment in construction amounts to $270 million, which is about 16 percent of Gallman's estimate of GNP (plus the value of farm improvements) for 1839. The calculation is 0.27/(1.54+.133), with the figures coming from tables A-1, A-3, and A-4.

[31] The value of the house comes from records associated with the 1798 Federal Direct Tax that imposed a tax on real property. The tax was repealed in 1802. See U.S. Archives (2011).

century.[32] As shown in figure 6b, the import share for nails (imports/domestic absorption) began a steady uptrend in the 1950s, rising to about 70 percent by the 1980s. The share appears to drop back in the 1990, though this shift could reflect, at least in part, a non-comparability between the data for 1992 and 2002 and the data for earlier years.[33] This rise in import shares is quite dramatic. Moreover, it came earlier than for many other manufactured goods likely reflecting that by 1950 the technology for producing nails was well understood and had become rather pedestrian.

The sharp rise in import shares raises an interesting question about the price series. If imports were rising so rapidly, what was happening to import prices and how does that compare to domestic prices? (This section is incomplete. So far, I only have the BLS series for import prices of nails and screws (and other fasteners) back to 1974. I should be able to track down unit values for imported nails and screws at a finer level of detail from other sources for earlier periods.) The rapid increase in imports starting in the 1950s coincides with a rapid increase in the matched-model index for the real price of nails. It seems a little puzzling that prices of domestically produced nails should rise so rapidly at a time that import competition was increasing.

For the period since 1974, I have measures of import prices, and figure 7a shows the matched-model index for real prices of nails (based on PPIs in this period) and "real" import

[32] I've only started to track down the early trade and tariff information. I infer from other sources that tariff policy was an important issue for the iron/nail/screw industry in the first part of the 1800s. The AISA data indicate that by the 1870s, imports were pretty inconsequential and did not become important until after the second World War.
[33] The data in figure 6b are calculated from the AISI data on imports, exports, and production (but using the Census of Manufactures figures for the value of production for 1992 and 2002, possibly introducing a non-comparability).

prices calculated as the import price divided by the CPI.[34] Over this period, import prices fell quite a bit relative to the PPIs. Indeed, from 1974 to 2011, real import prices fell about 60 percent. The matched-model index moved down some through the early 2000s but then moved back above its 1974 level. This comparison of PPIs to import prices raises the question of possible mis-measurement in either the PPIs or the import price measure. In particular, why were domestic prices rising during a period of further competition from imports and what products was the PPI pricing as domestic production dropped back rather dramatically?[35] Along these lines, the BLS shift in 2005, to a very broad category of all hardware raises the possibility that they had trouble pricing basic nails and screws.

Finally, the rising import share raises the question of what price index to use to gauge prices faced by domestic *purchasers*? If the PPIs and official measures of import prices are taken as correct, then perhaps the appropriate price index would be a weighted average of the PPI-based prices and import prices, using domestic and imported shares as weights.

4. Price Indexes for Screws

Raw Nominal Data and Conversion to Real Prices

Figure 8a plots the raw nominal price data for screws in cents per screws. Different colors highlight different data sources, and table 5 describes the sources and quotes in detail. (The data are reported in the Appendix.) The blue segment plots prices from the *Aldrich Report*

[34] The narrowest BLS import price series covers "Nails, screws, nuts, bolts, rivets of iron, steel, copper, or aluminum" from 1974 to 2005 and "Hardware manufacturing" thereafter. The series codes are EIUIM694 and EIUIZ3325, respectively.

[35] Indeed, Michael Mandel (2011) noted in a 2011 blog post that the U.S. military had difficulty finding domestic sources of some basic screws and other simple hardware.

(U.S. Senate, 1893) for 1” long, #10 gauge screws. These prices are quoted as dollars per gross (144) screws and converted to cents per screw. The red segment plots prices from Sears catalogs for 1” long, size #8 wood screws from 1896 to 1973, priced in the catalog as cents per gross (144) screws. Screws were more of a specialty item than nails, and, even by the late 1800s, screws were, apparently, still sold in small lots. The black segment shows prices using various PPIs to extend the series to 2011. The final dot in the figure shows a price quote from fastenersuperstore.com for 1” size #8 screws in a 4000-piece lot. This observation is quite close to the value for the PPI extension of the Sears series.

I had a hard time finding price quotes earlier than 1840. I did find price quotes for 1749, 1760, and 1800 for screws in the U.K., and I converted these to cents per pound.[36] The actual price quotes for individual years are shown on a cents per screw basis as the hollow green dots.

I also found price relatives spanning 1800-1849 and 1849-1866 from an 1866 account (Chamberlain) of the U.K. screw industry. Although Chamberlain did not cite actual prices, he reported how much the price of screws changed over those periods. In particular, these price relatives indicated that the price in 1866 was 1/5 of that in 1800.[37] I used these price relatives as follows to impute an alternative set of prices. First, I used the price relative between 1800 and 1866 to impute a price for 1800. Finally, I used the percent change in the raw price quotes from

[36] To convert the quotes to cents per pound sterling, I converted the 1749 and 1760 quotes to 1792 equivalents using the U.K. RPI from the Measuring Worth website. I then used the dollar/pound sterling exchange rate in 1792 to convert these quotes to dollars. Finally, I used the RPI to bring them back to 1749 and 1760. Put another way, I just used the 1792 exchange rate of $4.47 per pound sterling to convert these to a dollar basis. As with nails, these early quotes capture movements in U.K. prices converted to dollar basis. For the 1800 quote, I converted it to a dollar basis using the 1800 exchange rate from the Measuring Worth website of $4.55 per pound sterling.

[37] Chamberlain also reported price relatives for 1849, noting that the price in 1849 was 2/5 that of 1800 and that the price in 1866 was ½ that of 1849. The price relative between 1849 and 1866 is not consistent with data from the *Aldrich Report.* The *Aldrich Report* indicates that prices rose between 1849 and 1866 rather than falling as indicated by Chamberlain. This discrepancy could reflect many factors, including that Chamberlain was referring to prices in the United Kingdom.

1760 to 1800 and from 1749 to 1760 to extend back the price for 1800 imputed from the relatives. These alternative prices are shown as the solid green dots in figure 8a.

Interestingly, the prices imputed from relatives are much higher than the raw price quotes. These differences could reflect a number of shortcomings of the imputed prices based on price relatives. Perhaps the most significant source of difference is non-comparable quality. The descriptions that accompany the early quotes for screws are quite sparse so it is hard to know the quality—or in some cases the size—of what is being priced. Moreover, the evidence suggests that early screws were of very low quality relative to screws made in later periods. So, the large difference between the actual and imputed prices for the early period could reflect differences in quality. If this hypothesis is correct, then the imputed prices could be doing a better job of controlling for changes in quality. Of course, the imputed prices would be for products of a quality that was not yet available in the earlier period.

Figure 8b shows real prices of screws on a cents per screw basis, relative to the CPI, using the same CPI index that was used to deflate nails. These are the raw data whose quality adjustment is discussed in the next subsection.

One last data issue before getting to quality adjustment. Returning for a moment to price quotes for screws from Sears catalogues, note that I could have started using PPIs in 1948. And, the argument made above for nails—that Sears' margin might have grown in the 1950s as its prices for nails shifted from being closer to wholesale prices to being closer to retail prices—would suggest that I should have started with the PPIs as early as possible. However, as shown in figure 9, price quotes from Sears for screws rise more slowly from 1948 to 1973 than do prices implied by the PPIs. Thus, the margin story does not seem to work for screws. This

observation could raise questions about whether the margin story is right for nails. Without further digging into Sears' marketing practices, it's hard to really know. Nonetheless, given that Sears always listed screws in its catalogues in small lots, it is at least possible that they always had a more retail-like markup on screws. Moreover, the series that starts with the PPIs in 1973 (the blue line) lines up almost exactly with the price quote for 2011 from fastenersuperstore.com.

Quality Adjustment

The discussion above already raised a quality issue for screws; namely, the unknown quality associated with the price quotes for the earlier periods. A related issue is what happened to the holding power of screws over the full time span?

Starting with the price quotes from 1840-1891 from the *Aldrich Report*, these quotes are for #10 size screws, slightly larger in diameter than the #8 size screws priced from 1896 forward. The larger screws have greater holding power so I scaled down the prices during 1840-1891 by roughly 15 percent to account for this difference.[38]

In addition, some adjustments need to be made for the earlier price quotes when screws were of lower quality. Suppose that we take seriously the statement by Chamberlain (1866) that screws in the early period could not compete with nails. It is, of course, difficult to know exactly what that statement means, but suppose it is interpreted as meaning that we could think of early screws—from prior to the earliest machine production began in 1776—as having roughly the same holding power as nails. That probably is not literally true, but seems like a plausible starting point making quality adjustments.

[38] As discussed below, the formula for the holding power of a screw is linear in the diameter of the screw. Given that the diameter of a #8 size screw is about 85 percent of the diameter of a #10 size screw, the appropriate scaling factor to adjust for differences in holding power amounts to a 15 percent reduction in the prices during 1840-1891.

Based on formulas in *USDA Forest Service* (2002), it is possible to directly calculate the holding power of, say, a 1" screw and 1" wire nail. In particular, the relevant formulas indicate a holding power for the screw of 315 pounds and of 64 pounds for the wire nail.[39] The figure for the wire nail would imply a holding power of 128 pounds for a *forged* nail of 1" (using the factor described above that cut nails have twice the holding power of wire nails). Further, assume that screws had developed to their current quality by 1864, the year that a U.S. standard for threads was adopted, while in 1776 screws had the same holding power as a forged nail. Finally, assume that the quality improved in a linear fashion from 1776 to 1864 so that I can linearly interpolate the adjustment factor for holding power.

Under these assumptions, I can adjust the actual price quotes for 1749, 1760, and 1800 (the open dots in figure 8b) as well as the price quotes from 1840 to 1863. In particular, with the holding power of a screw in 1749 and 1760 assumed to equal 128 pounds (compared with an 1864 holding power of 315 pounds), I multiply the price in 1749 and 1760 by 2.46 (=315/128) to adjust the 1749 and 1760 prices to the holding power available in 1864 equivalent. By 1800, quality has improved a bit under the assumption of a linear improvement in quality from 1776 to 1864. Thus, the scale factor of 2.46 that was used for the 1749 and 1760 adjustments is downweighted. The downweight factor is 0.727 [=1-(24/88)] where 24 is the number of years between 1776 and 1800 and 88 is the number of years between 1776 and 1864. Accordingly, I multiply the 1800 price by 1.78 (=0.727 x 2.46) to adjust the 1800 price to put its holding power on an 1864 equivalent. Using the same methodology, I also adjusted prices from 1840 to 1863, under the assumption that screws did not achieve their current quality until 1864.

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39 The formula for screws is $p = 15700 \times G^2 \times D \times L$, where p is the holding power (or load) in pounds, G is the specific gravity of the wood, D is the diameter of the nail, L is the length of the nail (p. 152). The formula for nails is $p = 7850 \times G^{5/2} \times D \times L$ (p. 145). For white pine, the specific gravity is 0.35. For #8 screws, I used a length of 1 inch and a diameter of 0.164 inch. For nails, I used a length of 1 inch and a diameter of 0.113 inch.

These adjusted prices—on a real or CPI-adjusted basis—are plotted in figure 10a, with the green Xs showing the adjusted figures for 1749, 1760, and 1800. Interestingly, the observations based on these holding-power adjustments for 1749, 1760, and 1800 lie in between the actual price quotes (the open dots) and the alternative prices derived from price relatives (the solid dots).

Finally, I combined the Sears/PPI quotes with the adjusted *Aldrich* Report quotes to construct a matched-model index, and this index is plotted in figure 10b, along with early price quotes adjusted for holding power. (I did not make further adjustments to the price quotes from before 1840.) To construct the matched model index, I needed a link to connect the last of the *Aldrich Report* quotes in 1891 with the first of the Sears quotes in 1896, and I used the change in the real price of wire nails for this purpose.

This matched model index is my preferred price series for screws. This price series tells roughly the same story as does the corresponding series for nails, but it leave more unanswered questions in its wake and suggests that conclusions need to be more tentative. From the mid 1700s to the late 1800s, the real price of screws fell by a factor of about 8 times. Like nails, the price dropped back somewhat in the latter part of the 1700s and then fell dramatically through the late 1800s. This drop by a factor or 8—less than the drop in the price of nails of about 15 times—reflects the same forces of the industrial revolution that brought down the price of nails. From the low point of the series around 1 cent per screw, prices then rise through 2011 to about 3 cents per screw. That increase of a factor of 3 is about the same increase as that for nails from their low point through to 2011. One puzzle about the price series for screws is that it bottoms out as early as it does, reaching its nadir in 1885. That seems pretty early given subsequent

technological developments (including electrification). So, some further digging will be required.

As noted, the development of socket drive screws (Robertson or Phillips) in the first half of the 20th century facilitated manufacturing processes and the use of power drivers. And a couple of anecdotes suggest that the adoption of socket headed screws provided a noticeable boost to productivity. Rybczynski (2000, p. 84) cites a 1938 letter to the American Screw Company from a builder of boats and gliders that reported that the company's workers saved 30 to 60 percent of their time by using Phillips-headed screws rather than slotted screws. Another 1938 anecdote cited by Rybczynski reported a 75 percent boost in the amount that a worker could accomplish by using Phillips screws. Of course, it is hard to know how to interpret these anecdotes without further information about the firms' production processes, but they are suggestive of significant productivity gains. Moreover, after General Motors experimented with Phillips screws in a plant in 1936, virtually all auto plants adopted Phillips screws within two year. This rapid adoption suggests that the advantages were significant.

Implications and Interpretation

So far, I have had only limited success in tracking down quantity data for screws so I cannot repeat the sort of analysis done for nails. (I'm still hopeful that, with time, I can track down the relevant data.) Shaw (1947) does provide production data for wood screws based on data from the Census of Manufactures. For 1869, his data (combined with nominal GNP figures) show that the production of wood screws amounted to a little more than 0.02 percent of GNP, about 1/5 the share of nails. By 1919, the production of wood screws still amounted to about

0.02 percent of GNP, about ½ the share of nails. [40] Switching to a broader category reported in the Census of Manufactures that includes machine and other types of screws, production of screws amounted to 0.07 percent of GNP in 1919 and 0.10 percent in 1929. This share then dropped back to 0.06 percent in 1947 and 0.05 percent in 1954.[41] These figures suggest that, compared with nails, screws were becoming relatively more important as a share of GNP, at least through 1929. The share of screws (both wood and other types) appears to have continued rising through 1929 before turning down later, while the share of nails had been falling for a much longer time.

Identifying the downstream effects of the price decline for screws is both more subtle and perhaps more consequential than those for nails. The matched-model index developed here is for wood screws, so the downstream effects of price declines for those products likely showed up in construction and furniture. More generally, technological improvements in screw manufacturing contributed importantly to the development and improvement of many types of investment goods and consumer durables made. And, even more generally, threaded spindles, with finer and finer tolerances attainable, along with associated price declines, played an important role in the development of the machine-tool industry, with these spindles providing the control mechanisms for cutting and shaping machinery. And, the advent of Phillips and Robertson screw heads contributed to the use of power tools (and ultimately robots) in manufacturing. Indeed, Rybczynski (2000) suggested that the screw and screwdriver were the most important invention of the 2nd millennium.

[40] The share figures used for nails in 1869 and 1919 is based on Shaw's numbers so as to make it comparable with his number for wood screws. Recall that Shaw's figures for nails are not comparable to the AISI data for nails used above.

[41] The figures cited for machine screws (and the figures after 1919 for wood screws) are from the Census of Manufactures. Shaw made some adjustments to the raw figures for wood screws so his wood screw numbers do not match what is reported in the Census for 1919.

Comparing Prices of Nails and Screws

Figure 11a plots my preferred indexes for nails and screws (the two matched model series). As can be seen, screw prices were initially higher than nail prices with the gap between them narrowing through about 1885 as the price of screws falls relative to that for nails, but the gap then opens up from 1885 forward as the price of screws rises relative to that for nails. Figure 11b does the comparison another way, in terms of cents per hundred pounds of holding power.[42] Interestingly, on a comparable holding-power basis, nail and screw prices line up reaonably closely through about 1885. After that period, the real price of screws rises compared with nails, implying that a given amount of holding power became increasingly more expensive with screws than with nails.

5. Conclusion

This paper constructed long-span time series of prices for nails and screws. As documented, the relative price of nails and screws (relative to the CPI) dropped dramatically from the mid 1700s, and these price declines contributed to significant downstream changes in patterns of economic activity. The long-span price indexes provide a lens through which to see the major developments in manufacturing technology before, during, and after the industrial revolution. While nails and screws may now seem common and are generally taken for granted, in an earlier era they were anything but everyday.

[42] Because the matched-model price index for nails and screws should be keeping holding power constant over time, I can convert these indexes to 100 pounds of holding power with a single scale factor for each series. In particular, I divide the price series for nails by 1.28 and the price series for screws by 3.15. The adjustment for nails places 2 inch, size 6d nails on a hundred pounds of holding power basis. Similarly, the adjustment for the screw series places 1 inch screws on a hundred pounds of holding power basis.

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Wilder, Laura Ingalls (1935), *Little House on the Prairie*, Harper Collins, New York.

Table 1
Historical Time Line for Nails*

Roman era to 1820	Hand forged nails • Slitting equipment in Saugus, MA in 1645. (Lewis, p. 8.06.03) • From drawn iron rods up to about 1805 • Often made at home. • From machine rolled and cut iron rods starting in 1600s to about 1820 • Took a nailsmith about 1 minute to make a nail from a prepared blank (Rybczynski, p. 71)
1790s – early 1890s	Cut nails from sheets of iron or steel • First patents for cut nails in 1770s and 1780s. Flood of patents in following years. (Lewis, p. 8.06.09) • Cutting and heading machines in operation near Boston in 1794. (N&I, p. 8.06.09) • Cut nails became dominant by early 1800s • Machine headed starting around 1800 (Lewis, p. 8.06.09-8.06.10) • Improved rolling of iron and inline grain starting in 1820s, prevalent by 1830s • Increasing sophistication and automation of machinery (first water power and then steam power) • In 1880s, shift from iron to steel
1850s	Wire nails developed
1877	First American patent for wire nails (Adams, p. 69)
1880	Iron wire nails began to be manufactured in U.S. on large-scale
Late 1880s, early 1890s	Steel wire nails produced in sizable quantities
1920	Wire nails dominate (only 8 percent of produced nails were cut)
Early 1980s	Pneumatic nail guns appear in Sears catalogue for first time
Today	Fully automated machine makes 300-450 nails per minute (machinetools.com)

*Except where noted, source is Wells (1998).

Table 2
Historical Time Line for Screws

1500s	• First regular appearance of screws (Dickinson, p. 79) • Screws made by hand from forged blanks with threads filed by hand. Significant variation in shape and thread pitch. (White) • Took several minutes to make a screw (Rybczynski, p. 75) • Often made by builders of clocks, locks, watches, and guns (Rybczynski, p. 72)
mid 1700s	Screws became a commercial article (Dickinson, p. 80)
1760	First patent for making wood screws by machine (lathe and metal cutting tools) granted to brothers Job and William Wyatt (Dickinson, p. 80-81)
1775	Butt hinges patented (Dickinson, p. 80)

1776	• Wyatt brothers open screw factory in Birmingham, England. Sold to Shorthose, Wood & Co. (Dickinson p. 81)
	• Produce wood screw in about 6 or 7 seconds (Dickinson, p. 81 and Chamberlain p. 605)
	    o Blank cut to length
	    o Head made by a smith
	    o Slot cut by hand
	    o Blank chucked in jaws so that the blank could be rotated while blades cut a thread
	• Quality was low and screws could not, generally, compete with nails (Chamberlain, p. 605-606)

1810	First screw factories established in United States (Rhode Island) (Rybczynski, p. 77)
1830s	A boom in screw making in Rhode Island, though still using earlier production method. (Rybczynski p. 77)
1837	First of several patents for pointed screws (Dickinson, p. 84)
1842	Patent for completely automatic manufacture (Dickinson, p. 85)
1849	Process for fully automatic production of pointed screws (Dickinson, p. 85)
1864	U.S. Standard developed for screw threads (Kent, 1903)

1907	Patent for Robertson headed screw (square socket drive) (Rybczynski, p. 80)
1936	Patent for Phillips head screw (Rybczynksi, p. 83)
1936	Phillips screws tested by GM for 1936 Cadillac (Rybczynski, p. 84). Within a few years, most U.S. automakers had switched to Phillips screws.
Today	Fully automated machine makes ½ to 35 screws per minute, depending on the screws specs (machinetools.com)

Table 3
Nails: Data Sources for Prices

Dates	Nail Description	Quote	Source
1695 - 1792	Various, hand forged	Shillings/12 pounds, based on purchase records of Greenwich hospital. Converted to U.S. cents/lb using 1792 exchange rate of £1 = $4.47 from www.measuringworth.com	Beveridge (1939). No data are reported for selected years and values for these years are interpolated.
1784 - 1828	1814-1827 quotes for "cut nails," all sizes"; for other years, "assorted sizes." Earlier years may include forged nails.	Philadelphia market, quotes for various size lots,	Cole (1938)*
1828 - 1834	Nails, cut	New York market, $/100 lbs	1881 Report of the Director of the mint, p. 54*
1835 - 1849	Cut nails	$/100 lbs	Report of the Secretary of the Treasury, 1849.*
1850 - 1859	Cut nails	$/100 lbs	American Iron and Steel Association*
1860 -1890	Cut nails	$/100 lbs	American Iron and Steel Association*
1890 - 1947	Wire, 8d, fence and common	$/100 lbs	BLS reports*
1947 - 1960	Wire, common	$/100 lbs	BLS reports*
1962 - 1997	Wire, common, quoted at $/50 lbs. From 1992-98 "bright nails."	$/50 lbs	BLS reports For 1992-98, from PPI WPU10880211

1997-2009	Steel nails, staples, tacks, and spikes, made in plant that draw wire,	Index number	PPI, WPU108812012
2009 – 2011	Steel nails, staples, tacks, spikes, and brads, WPU10881201	Index number. 2011 value is average of January-May.	PPI, WPU10881201
Parallel Data			
1897- 1960	Wire, 6d, 2”, iron and steel, roughly for every 2nd or 3rd year.	$/100 lbs for 1897- 1932 $/lb for 1936 – 1940 $/5 lbs for 1942-1960	Sears Catalogues
2011	Wire, 6d common	$/50 lbs	www.amazon.com

*Prices reprinted in *Historical Statistics of the United States.*

Table 4
Count per Pound for 2" Nails

Period	Count	Source
1695 – 1889	85	Average from multiple sources*
1890 – 1941	150	Counts from various Sears catalogs for 2", 6d wire nails
1942 – 1944	181	Sears catalogs, 2", 6d wire nails
1945 – 2011	168	Sears catalogs and Grainger.com, 2", 6d wire nails

*****The Tremont Nail company currently advertises 2" 6d cut nails described as common, standard, at 85 per pound (see tremontnail.com). Lee Valley currently advertises 2" cut nails with wrought heads at 68 per pound and with rose heads at 97 per pound. A document from the early 1800s [*A List of Nails and Spikes Required for the Service of the Office of Ordnance* (1813), reprinted in the *Bulletin of the Association for Preservation Technology*] lists clasp-headed 2" cut nails at 100 per pound and clout 2" cut nails at 83 per pound. I took 85 as a reasonable value capturing this range.

Table 5
Screws: Data Sources for Prices

Dates	Screw Description	Quote	Source
1749	1”	5 doz @ 3 UK pence	Dickinson (1941-42, p 80)
1760	very fine	4 doz @ 6 UK pence	Dickinson (1941-42, p. 80)
1800	?	2 UK pence/dozen	Rybczynski (2000, p 76)
1840 – 1891	#10, 1”, wood screws, iron	$/gross of screws	U.S. Senate Aldrich Report (1893)
Price relatives: 1891 to 1896	?	Price of wire nails	
1896 – 1971	#8, 1”, wood screws. iron and steel	Cents/gross of screws. Quotes roughly every 2nd or 3rd year with missing segments interpolated	Sears Catalogues
1972	Assorted wood	extrapolated using 1971 and 1972 price for box of 200 assorted wood screws	Sears Catalogues
1972 – 1988	Bolts, nuts, screws, rivets, and washers	Index number	BLS, PPI, WPU1081
1988 - 2011	Tapping and wood screws	Index number. Percent change for 2011 is April divided by 2010 year average.	BLS, PPI, WPU10810236
Parallel Data			
Price relatives: 1800 to 1866	?	1866 1/5 of 1800	Chamberlain (1866, p. 608)

1849 to 1866	?	1866 ½ of 1849	Chamberlain (1866, p. 608)
1947 – 1972	Wood screws	Index number	BLS, PPI, WPU10810126
2011	#8, 1”, steel wood screw	$/4000 pieces	www.fastenersuperstore.com

Figure 1
Hand Forged, Machine Cut, and Wire Nails

Note: Forged nail at top, machine cut nail in middle, and wire nail at bottom.

Source: www.glasgowsteelnail.com/nailmaking.htm

Figure 2a

Nominal Price of Nails

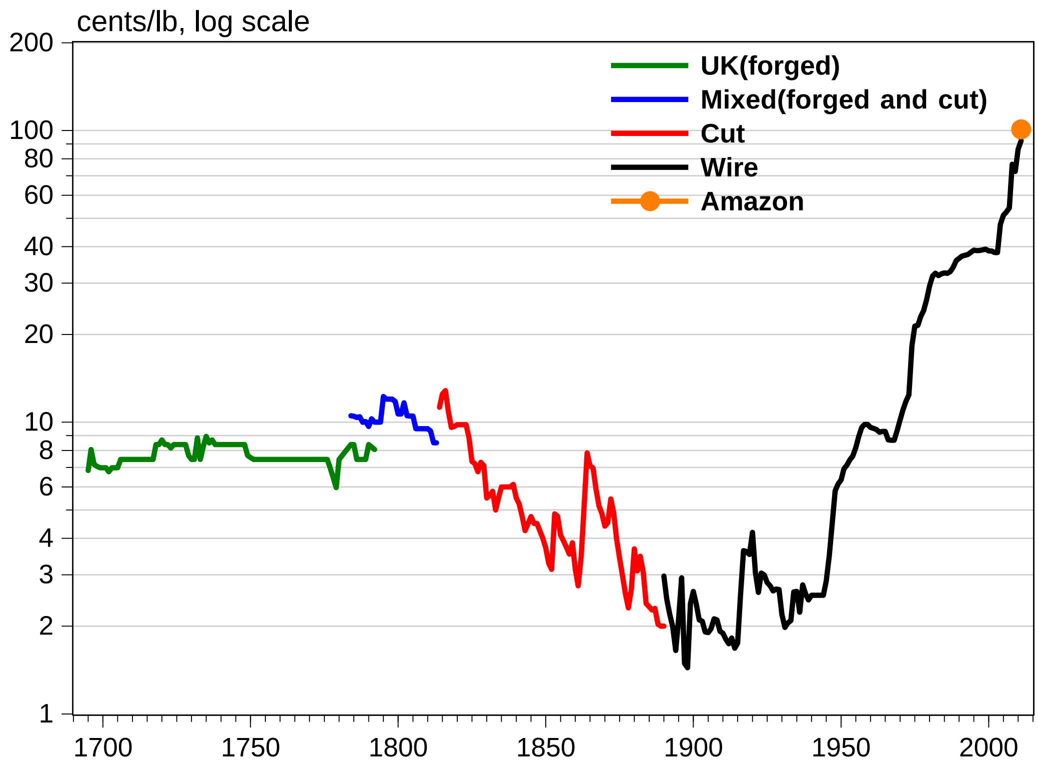

Figure 2b

CPI w/RPI splice

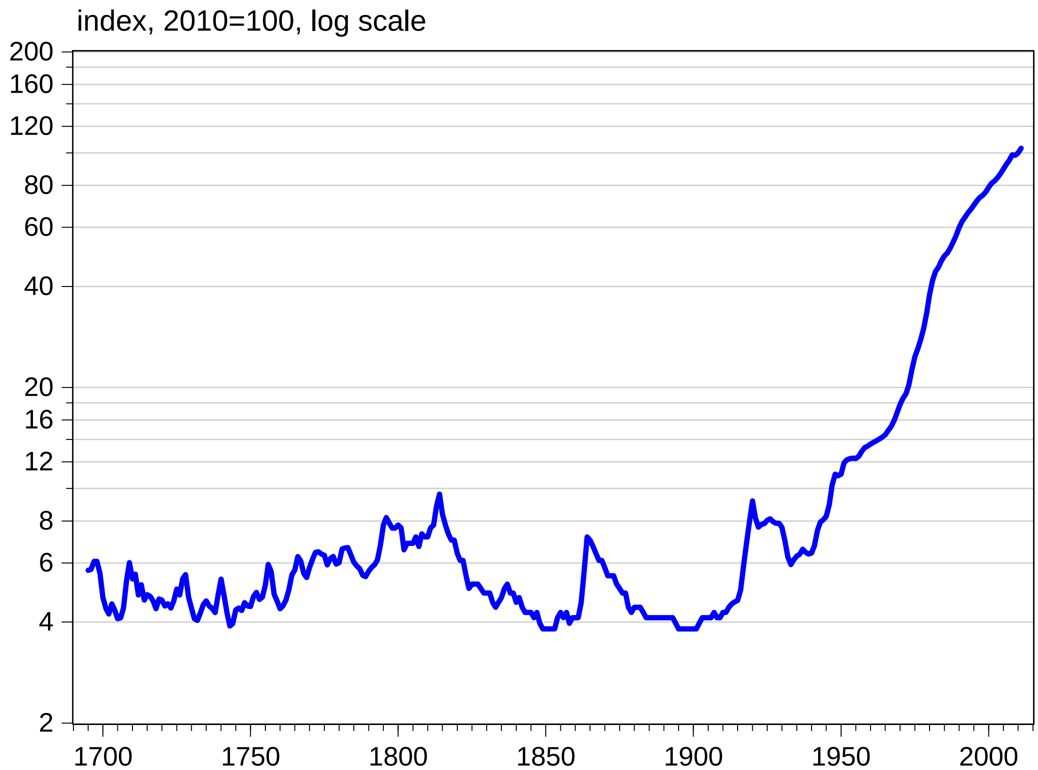

Figure 3a

Real Price of Nails (cents/lb)

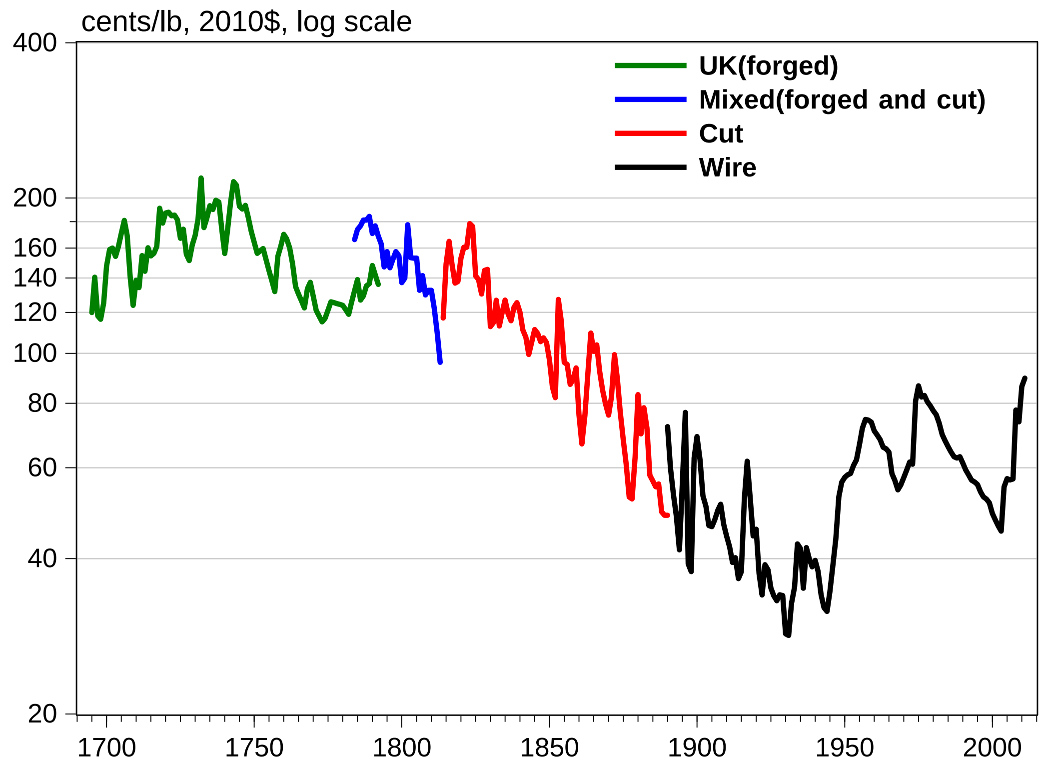

Figure 3b

Real Price of Nails (cents/nail)

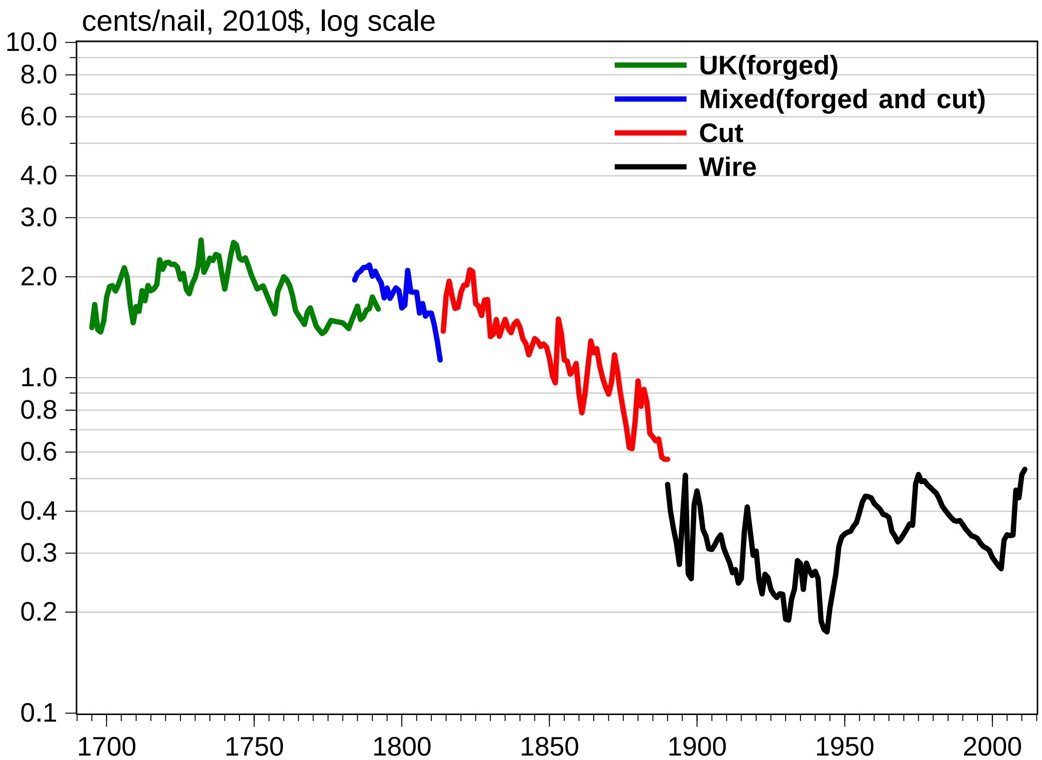

Figure 4a

Real Price of Nails

(dashed lines - constant holding power)

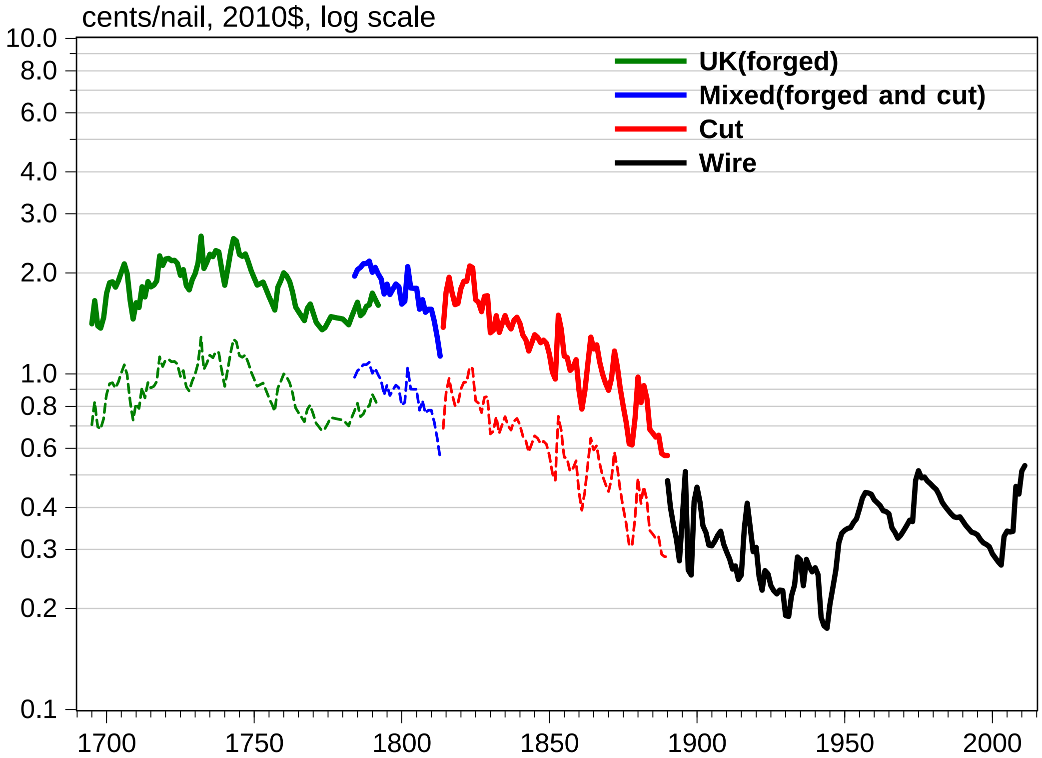

Figure 4b

Real Price of Nails: Matched-Model

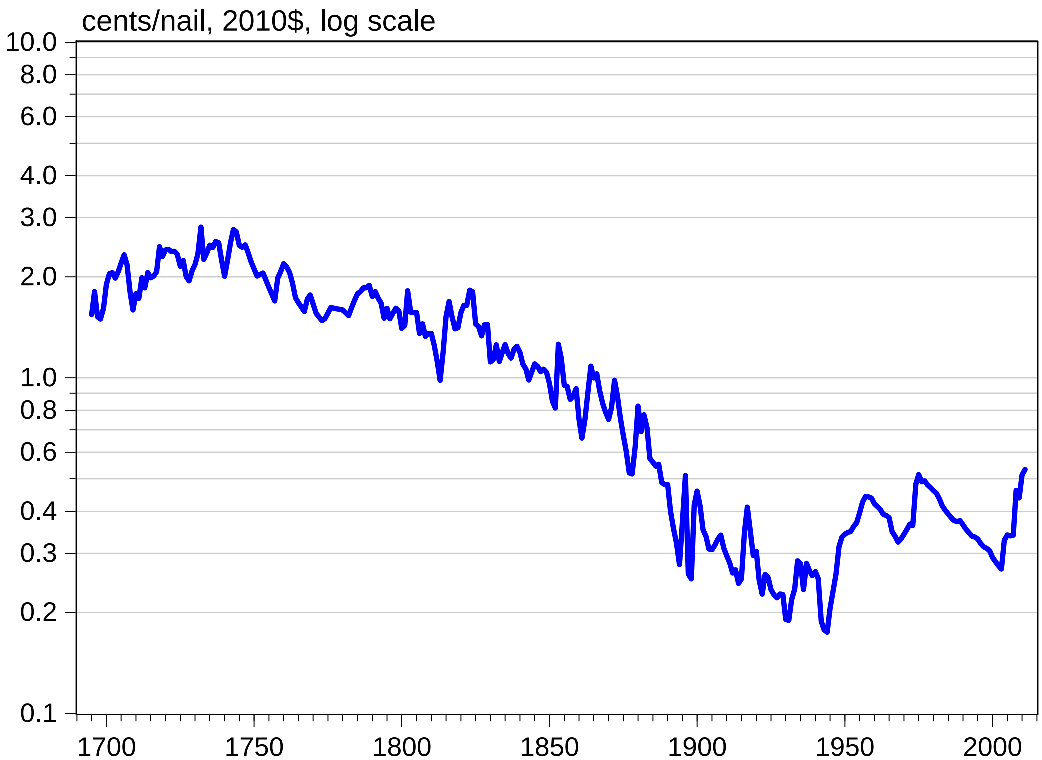

Figure 5a

Real Price of Nails (cents/lb)

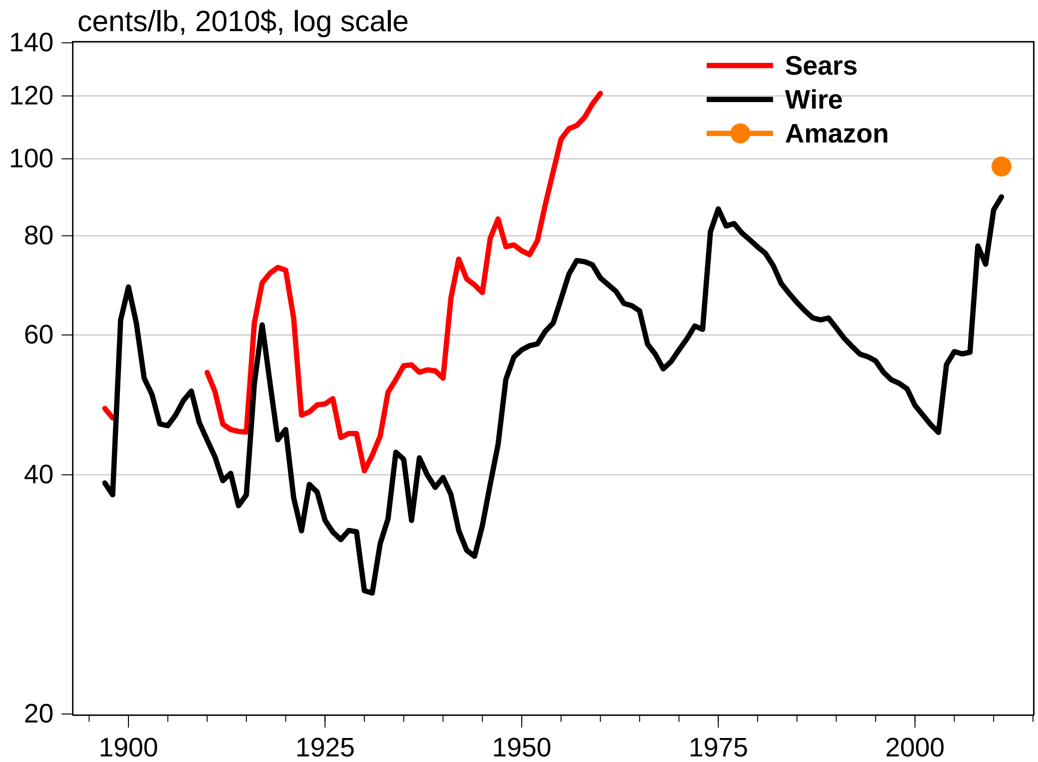

Figure 5b

Real Price of Nails (cents/nail)

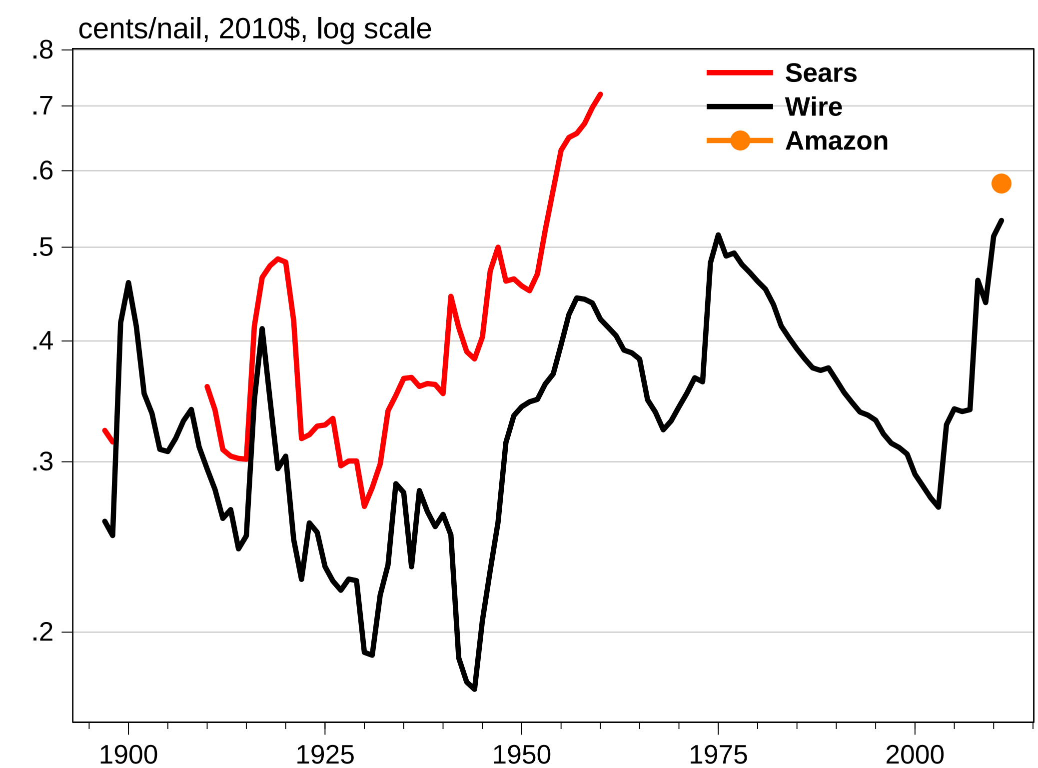

Figure 6a

Domestic Absorption of Nails in Thousands of Tons and Value as Share of Nominal GDP

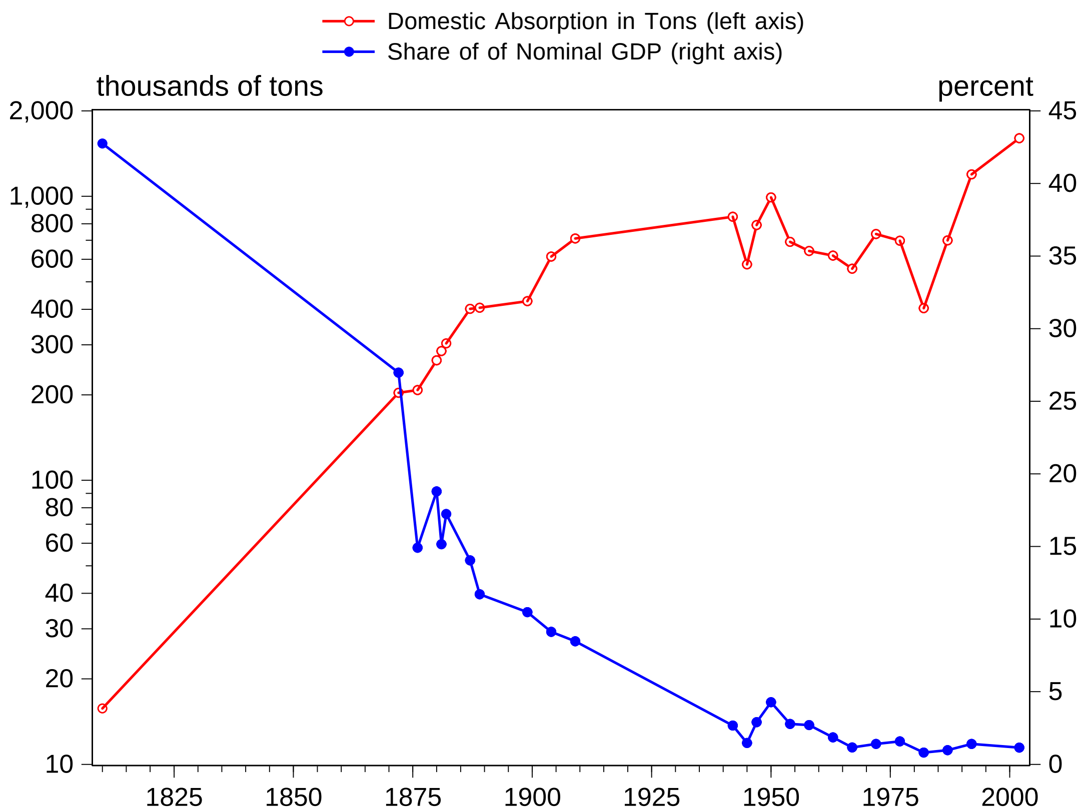

Figure 6b

Nail Imports as Share of Domestic Absorption

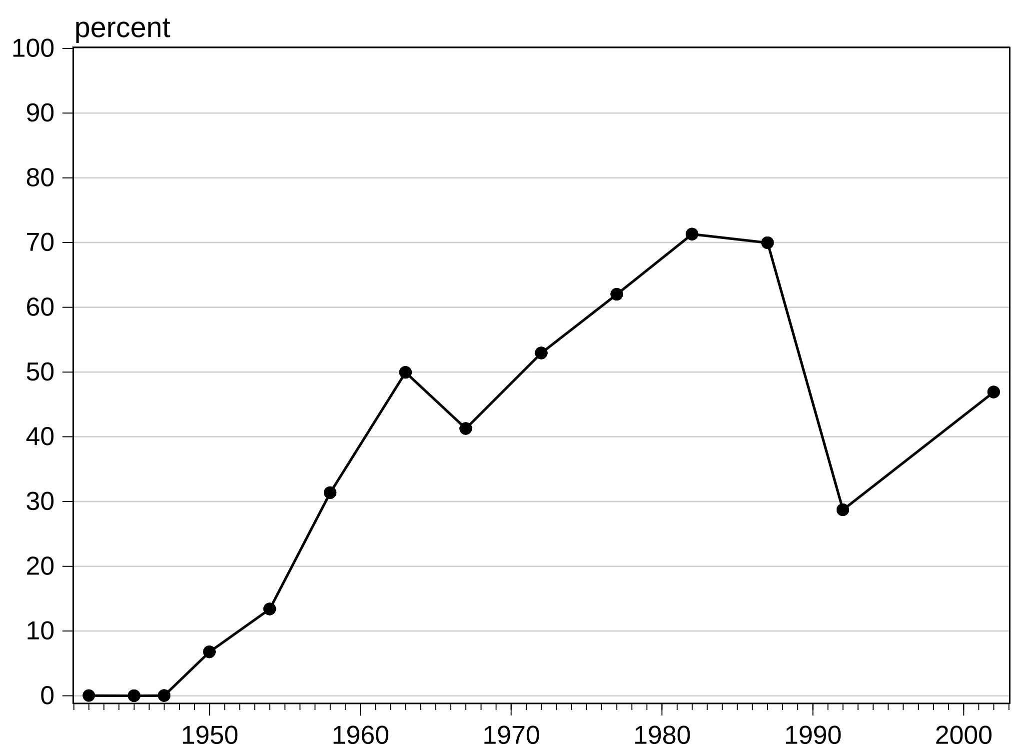

Figure 7a

Real Price of Nails and Imported Nails and Screws

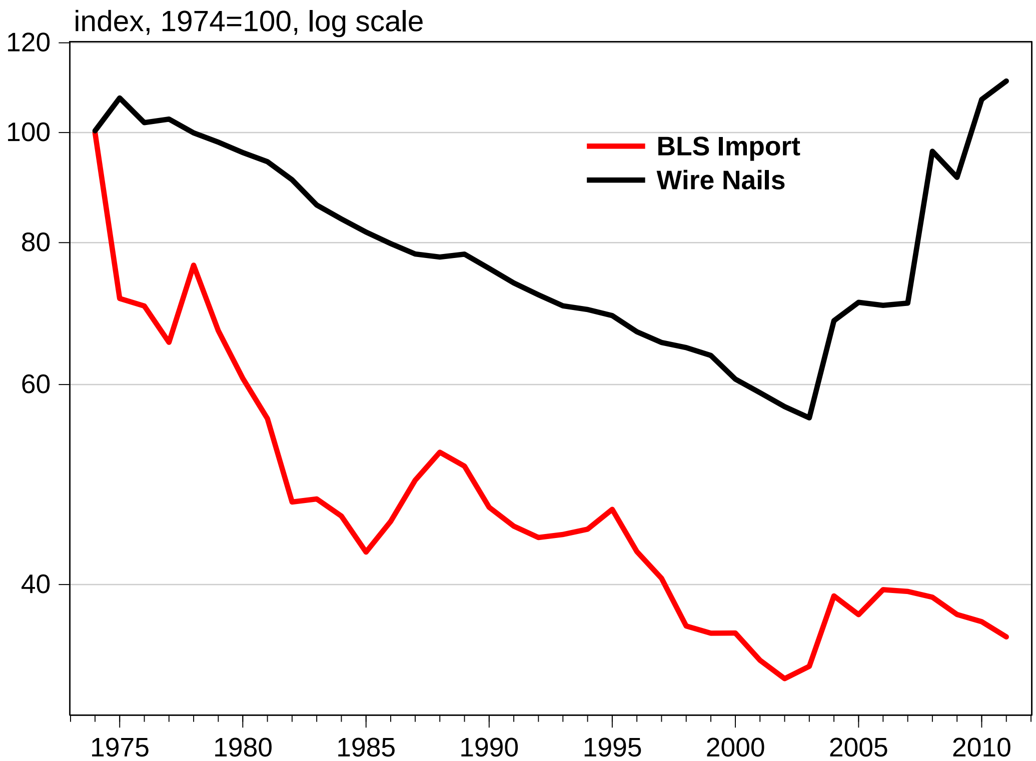

Figure 7b

Real Price of Screws and Imported Nails and Screws

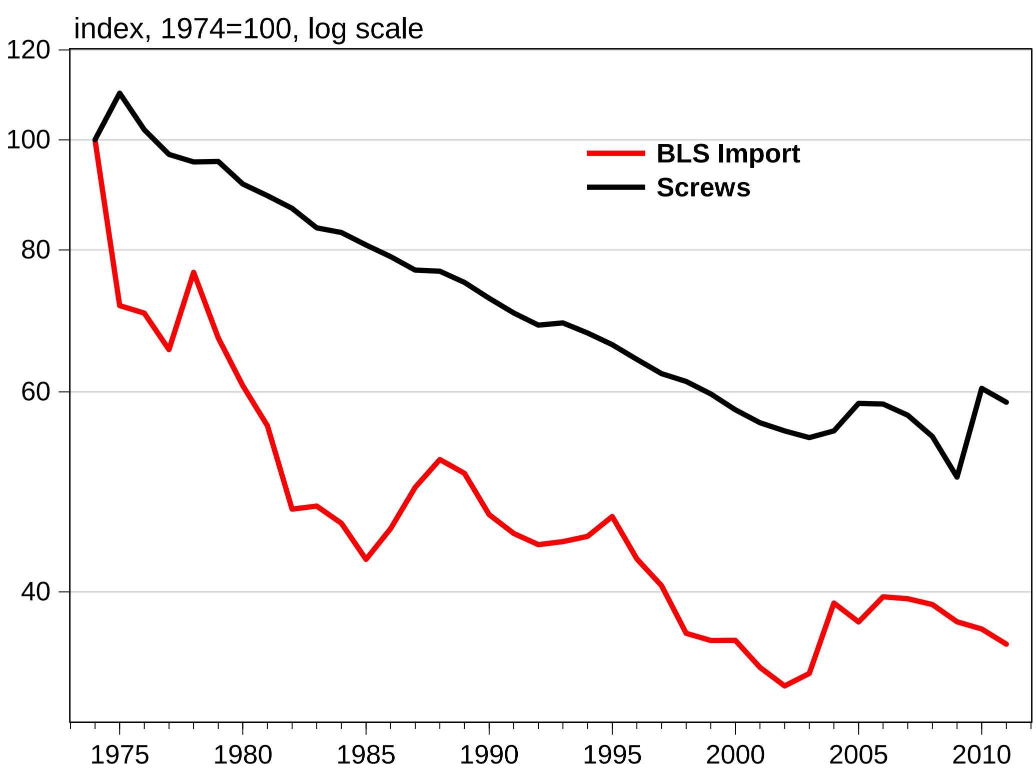

Figure 8a

Nominal Price of Screws

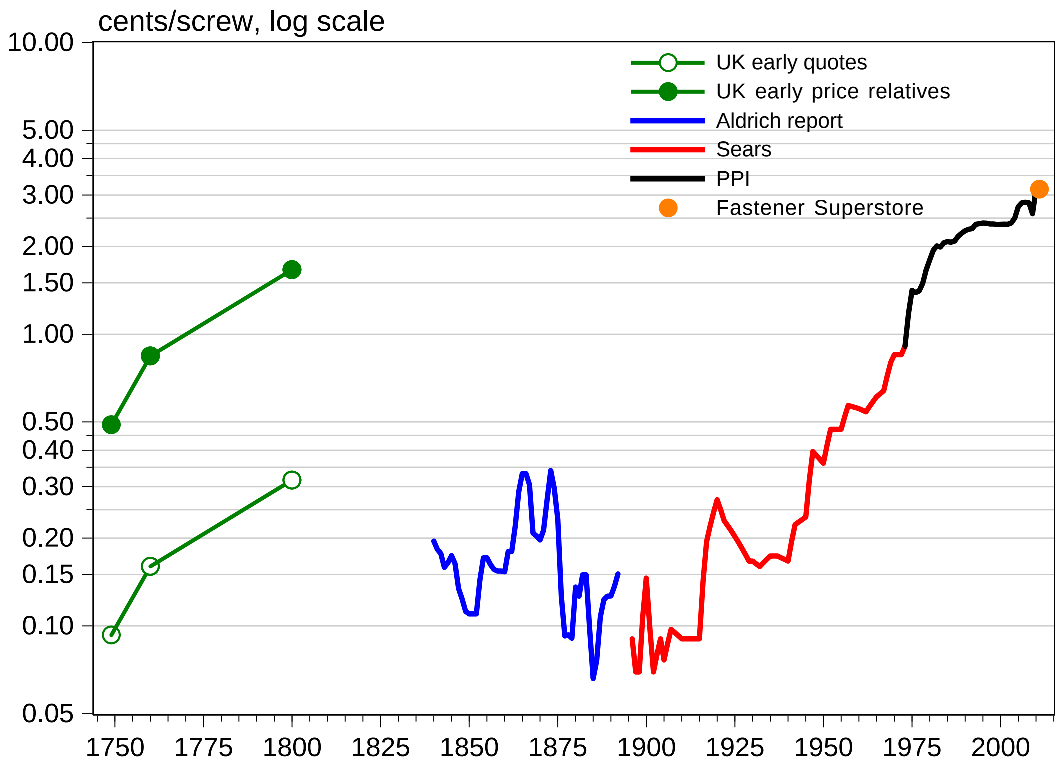

Figure 8b

Real Price of Screws

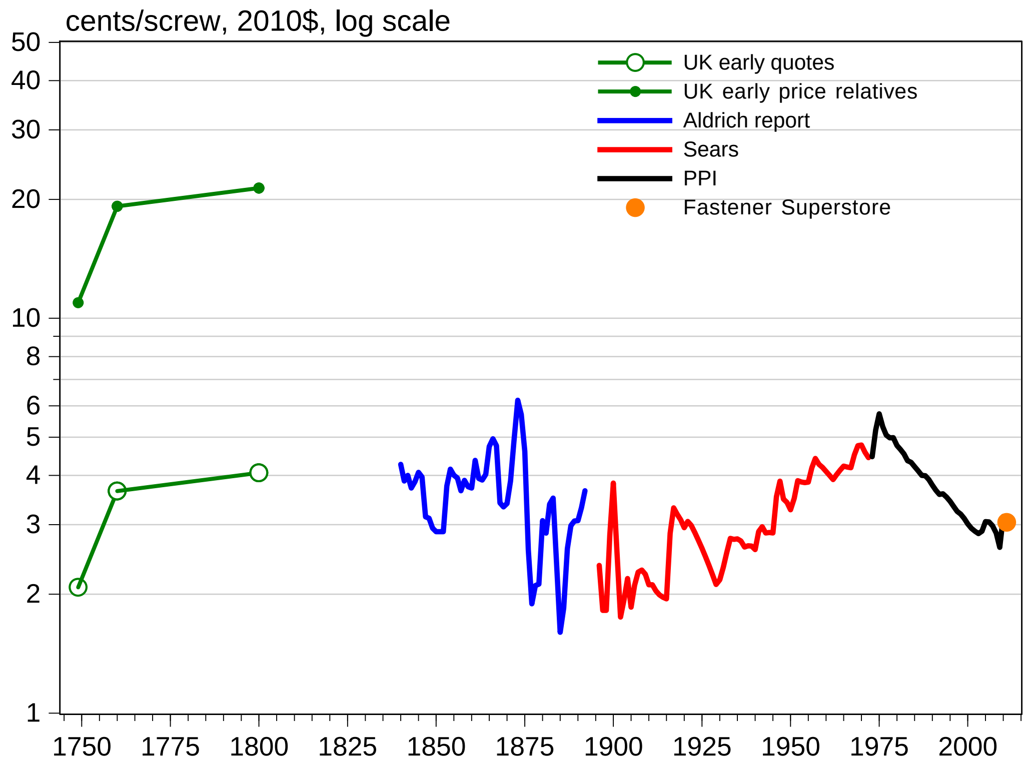

Figure 9

Real Price of Screws

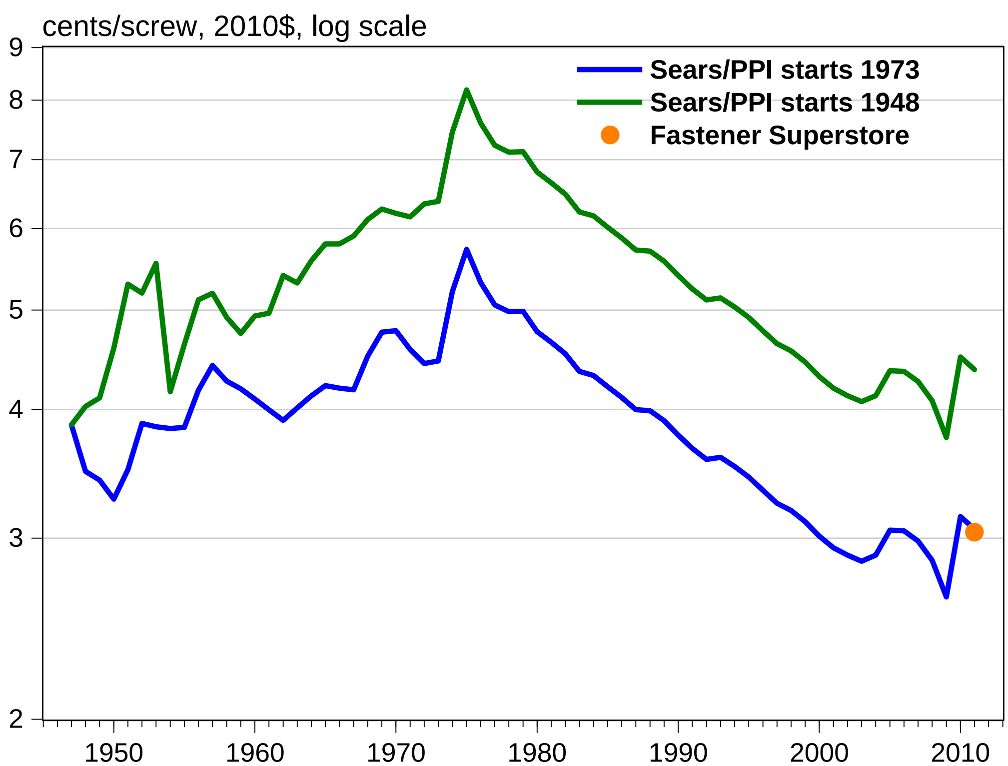

Figure 10a

Real Price of Screws

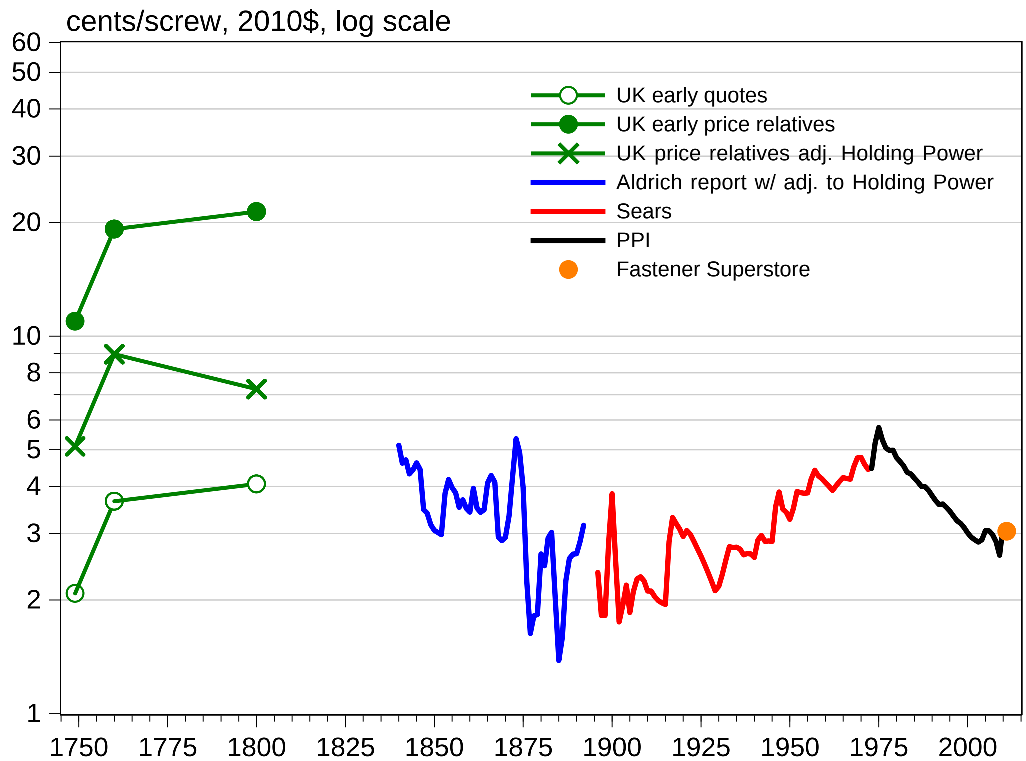

Figure 10b

Real Price of Screws: Matched-Model Index

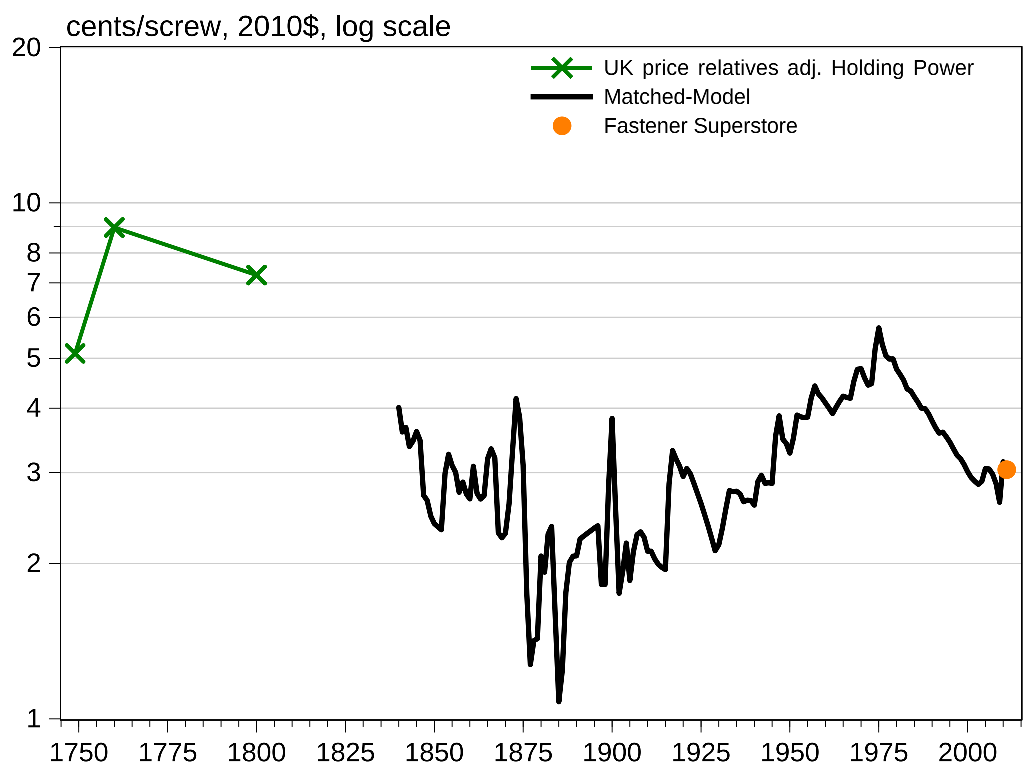

Figure 11a

Real Price of Nails and Screws: Matched-Model Indexes

(cents per Nail or Screw)

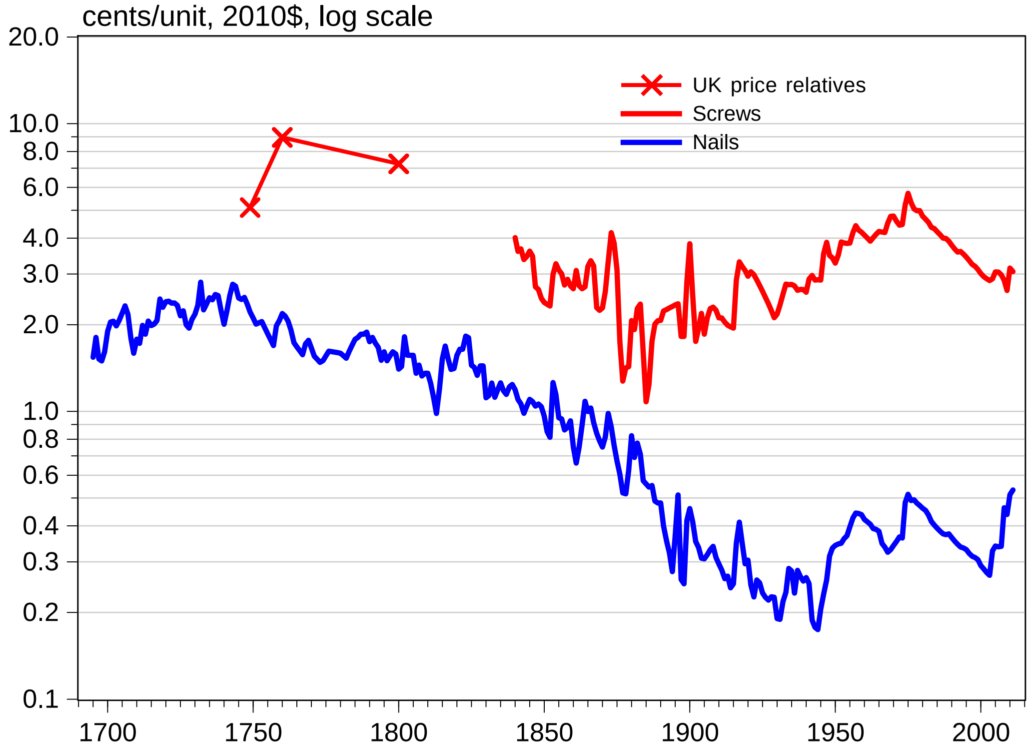

Figure 11b

Real Price of Nails and Screws: Matched-Model Indexes

(cents per 100lb. of holding power)